Snake River - Hells Canyon Total Maximum Daily Load (TMDL)

Section 2.0 Subbasin Assessment

2.0 Subbasin Assessment

2.0.1 Introduction and General Information

This document represents the subbasin assessment and preliminary problem statement for the Snake River - Hells Canyon (SR-HC) Total Maximum Daily Load (TMDL). The SR-HC TMDL is a joint effort between the Idaho Department of Environmental Quality (IDEQ) and the Oregon Department of Environmental Quality (ODEQ), with participation by the US Environmental Protection Agency (US EPA) and local stakeholders.

The overall goal of the SR-HC TMDL is to improve water quality in the SR-HC TMDL reach by reducing pollution loadings from all appropriate sources to attain water quality standards and restore full support of designated beneficial uses within the SR-HC TMDL reach.

The scope of this TMDL extends from where the Snake River intersects the Oregon/Idaho border at Snake River mile (RM) 409 near Adrian, Oregon and Homedale, Idaho, to immediately upstream of the inflow of the Salmon River (RM 188) including Hydrologic Units (HUCs) 17050115, 17050201 and 17060101, and a small corner of 17050103. Figure 2.0.1 is a map of the geographic area within the scope of the SR-HC TMDL. The scope includes free-flowing sections of the river and the Hells Canyon Complex reservoirs: Brownlee, Oxbow and Hells Canyon. For the purposes of this document, the SR-HC TMDL reach has been divided into five segments: the Upstream Snake River segment (RM 409 to 335); the Brownlee Reservoir segment (RM 335 to 285); the Oxbow Reservoir segment (RM 285 to 272.5); the Hells Canyon Reservoir segment (RM 272.5 to 247); and the Downstream Snake River segment (RM 247 to 188).

Two major geographical descriptions will be used in this document: the SR-HC TMDL reach and the SR-HC watershed. The SR-HC TMDL reach is defined as the specific HUCs designated above (17050115, 17050201 and 17060101, and a small corner of 17050103) which contain the Snake River from RM 409 to RM 188 and comprise approximately 2,500 square miles of land immediately adjacent to the river. The scope of the SR-HC TMDL includes the area contained within the SR-HC TMDL reach.

The SR-HC watershed encompasses the SR-HC TMDL reach **and** the drainage areas of all tributaries inflowing to the SR-HC TMDL reach. It is a large and complex area, extending some 73,000 square miles. Because the SR-HC watershed is the source of inflowing tributaries, it is therefore potentially the source of tributary-based pollutant loads to the SR-HC TMDL reach. A discussion of the SR-HC watershed is included where appropriate in this document as it provides a necessary framework for the evaluation of water quality parameters, pollutant loading, and potential benefits from implementation measures identified by upstream TMDLs and water-quality processes.

This document (subbasin assessment, loading analyses, load allocations, implementation plans and associated appendices) constitutes the SR-HC TMDL. The SR-HC TMDL provides an assessment of the current water quality status in the reach; identifies probable causes of designated beneficial use impairment within the waterbody; identifies water quality targets and

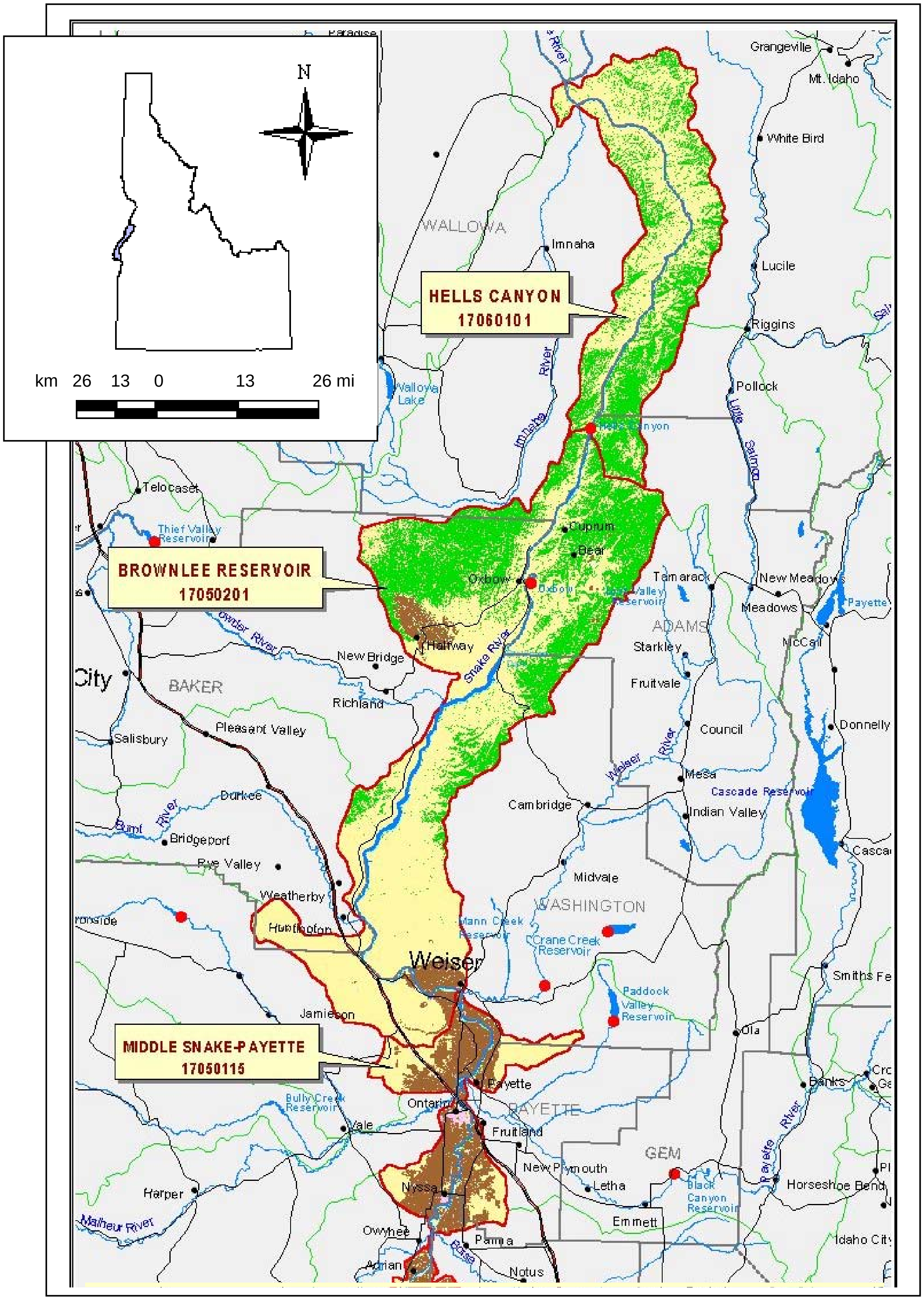

Figure 2.0.1 Geographical scope of the Snake River – Hells Canyon TMDL.

pollutant load reductions that will result in full support of designated beneficial uses; allocates pollutant loads to identified sources within the SR-HC TMDL reach and identifies the general structure for implementing the measures necessary to meet water quality targets as outlined by the TMDL.

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2.1 Characterization of the Watershed

The Snake River Basin includes areas of Idaho, Nevada, Oregon, Utah, Washington and Wyoming. The Snake River is the 10th longest river system in the United States, extending over 1000 miles from its headwaters in Yellowstone National Park, Wyoming, to its confluence with the Columbia River near Pasco, Washington (see Figure 2.1.1). Over its length, the river falls nearly 7,000 feet in elevation. It passes through some of the richest farmland, and the deepest canyons in North America. The Snake River is the major tributary to the Columbia River system. It drains about 87 percent of the State of Idaho (roughly 73,000 square miles); approximately 17 percent of the State of Oregon (about 16,900 square miles) and over 18 percent of the State of Washington (approximately 19,600 square miles). The Snake River flows nearly 760 miles through southern and southwestern Idaho, with about 270 miles of this segment acting as the border between Oregon and Idaho. Near the town of Lewiston, the Snake River leaves Idaho (having left Oregon upstream near China Garden Creek), traveling the remainder of its length westward across Washington to its confluence with the Columbia River.

2.1.1 Physical and Biological Characteristics - Historical and Current

As outlined above, the scope of this document encompasses a very large and diverse geographical area (Figure 2.0.1). Conditions within this system vary ecologically, geologically and hydrologically between upstream and downstream segments. Ecological variations within the river system are evident in the changes in climate, vegetation, animal populations and fisheries throughout the listed segments. Geologic variations such as changes in elevation, soil, rock type, landforms and relative impact of naturally occurring erosive processes are observed upstream to downstream. Equally evident are the hydrologic variations that occur with distance traveled from the fast-flowing upstream section of the river, through the slower-flowing, more lacustrine (lake-like) reservoir systems, to the rapid, white-water sections downstream of Hells Canyon Dam. In addition to changes in flow and velocity, hydrologic variations include differences in relative ground and surface-water inflows and channel morphology throughout the listed segments. Variations in water quality and quantity also occur over time. Temporal variations cover a wide range of factors including historical vs. current land use and river management conditions, changes induced by differences in flow and precipitation in a wet year vs. a dry year, and seasonal variations. Each of these categories is explored in greater detail in the following sections.

2.1.1.1 ECOLOGY

Climate

The climate of the SR-HC TMDL reach of the Snake River is hot and dry in the summer and cold and dry in the winter. Precipitation is bi-modal with intense, short duration summer storms and milder, longer duration winter storms. Much of the water in this reach is derived from snowmelt runoff from high elevations and upstream reaches of the mainstem Snake River and the inflowing tributaries. Only minor differences in precipitation and temperature occur from the upstream to downstream segments of the SR-HC TMDL reach. However, major differences in precipitation and temperature occur within the tributary watersheds that feed into this reach of the Snake River.

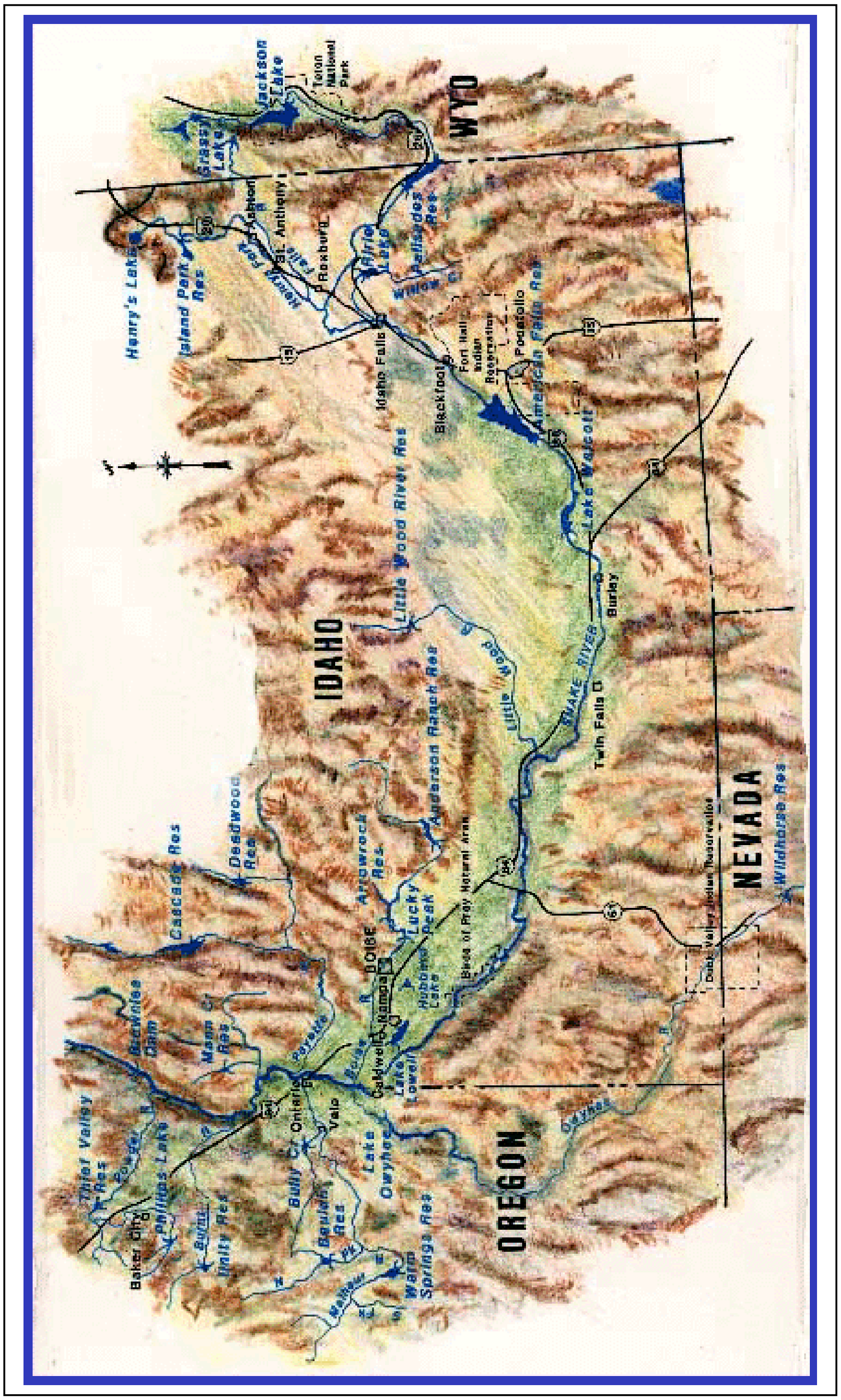

Figure 2.1.1 Snake River Basin Area, including portions of Oregon, Idaho, Nevada and Wyoming.

As shown in Figure 2.1.2, precipitation measured from 1961 to 1990 averaged approximately 11.3 inches per year at Weiser, Idaho (located within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach). The maximum recorded annual precipitation in this area during this time frame was 16.3 inches (1970). During the same period of record, precipitation in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach (measured near Lewiston, Idaho) averaged 12.4 inches annually. The maximum precipitation recorded in this downstream area during this period was 15.4 inches (1971). The total difference in average precipitation levels observed upstream to downstream is 1.1 inches (8.9%) over the period of record.

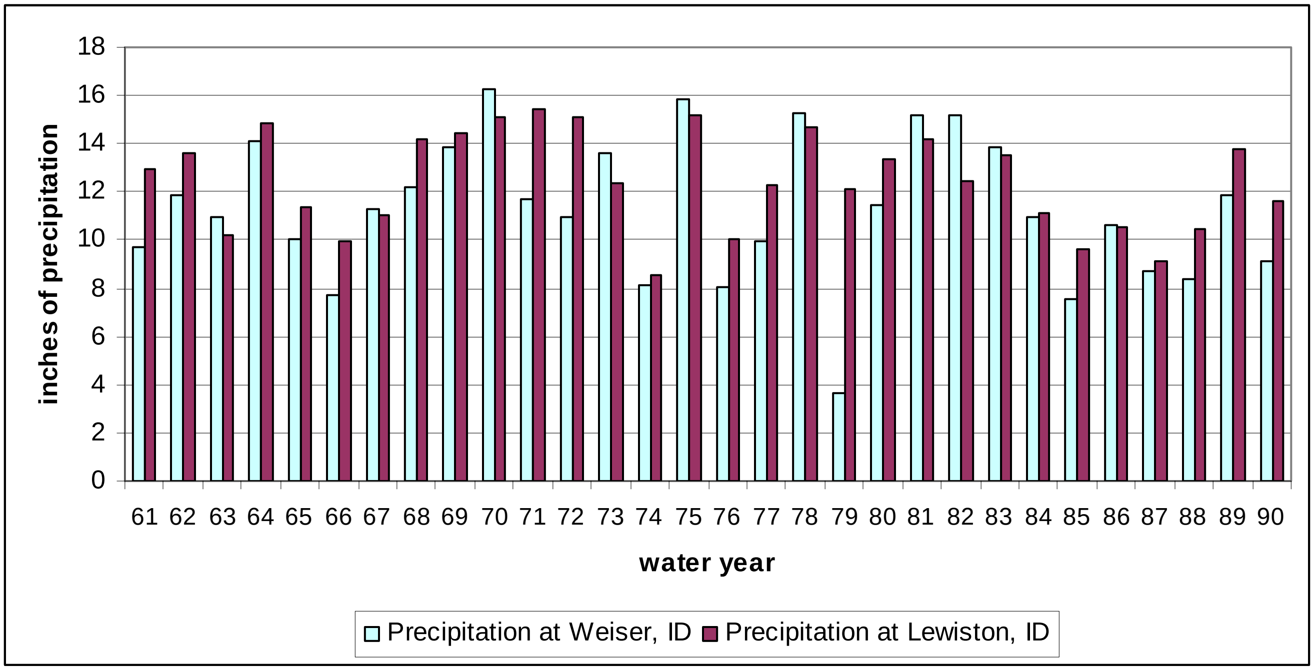

Figure 2.1.2 Mean precipitation in inches for two sites in the area of the Snake River - Hells Canyon TMDL (Weiser, ID at RM 351 and Lewiston, ID at RM 139, downstream of the TMDL reach).

As shown in Figure 2.1.3 (SNOTEL, 2000), summer high air temperatures averaged 23.8 ^{o}C (74.9 ^{o}F) in the Upstream Snake River segment (RM 409 to 335), with a daily maximum air temperature average of 32.7 ^{o}C (90.9 ^{o}F) from 1961 to 1990. Over the same period of record, summer high air temperatures averaged 23.4 ^{o}C (74.1 ^{o}F) in the Downstream Snake River segment (RM 247 to 188), with a daily maximum air temperature average of 31.7 ^{o}C (89.0 ^{o}F). Winter low air temperatures during the same time period averaged -2.3 ^{o}C (27.8 ^{o}F) in the Upstream Snake River segment (daily minimum air temperature average of -6.3 ^{o}C (20.7 ^{o}F)) and 0.9 ^{o}C (33.6 ^{o}F) in the Downstream Snake River segment (daily minimum air temperature average of -2.5 ^{o}C (27.6 ^{o}F)). The average air temperature difference upstream to downstream was 1.2 ^{o}C (2.1 ^{o}F) (ranging from 3.2 ^{o}C (5.8 ^{o}F) in January down to 0.36 ^{o}C (0.65 ^{o}F) difference in August) for daily average air temperatures; 1.3 ^{o}C (2.3 ^{o}F) (ranging from 2.6 ^{o}C (4.7 ^{o}F) in June down to 0.2 ^{o}C (0.4 ^{o}F) difference in November) for daily maximum averages; and 1.9 ^{o}C (3.4 ^{o}F) (ranging from 6.9 ^{o}C (3.8 ^{o}F) in January down to 0.1 ^{o}C (0.2 ^{o}F) difference in May) for daily minimum averages.

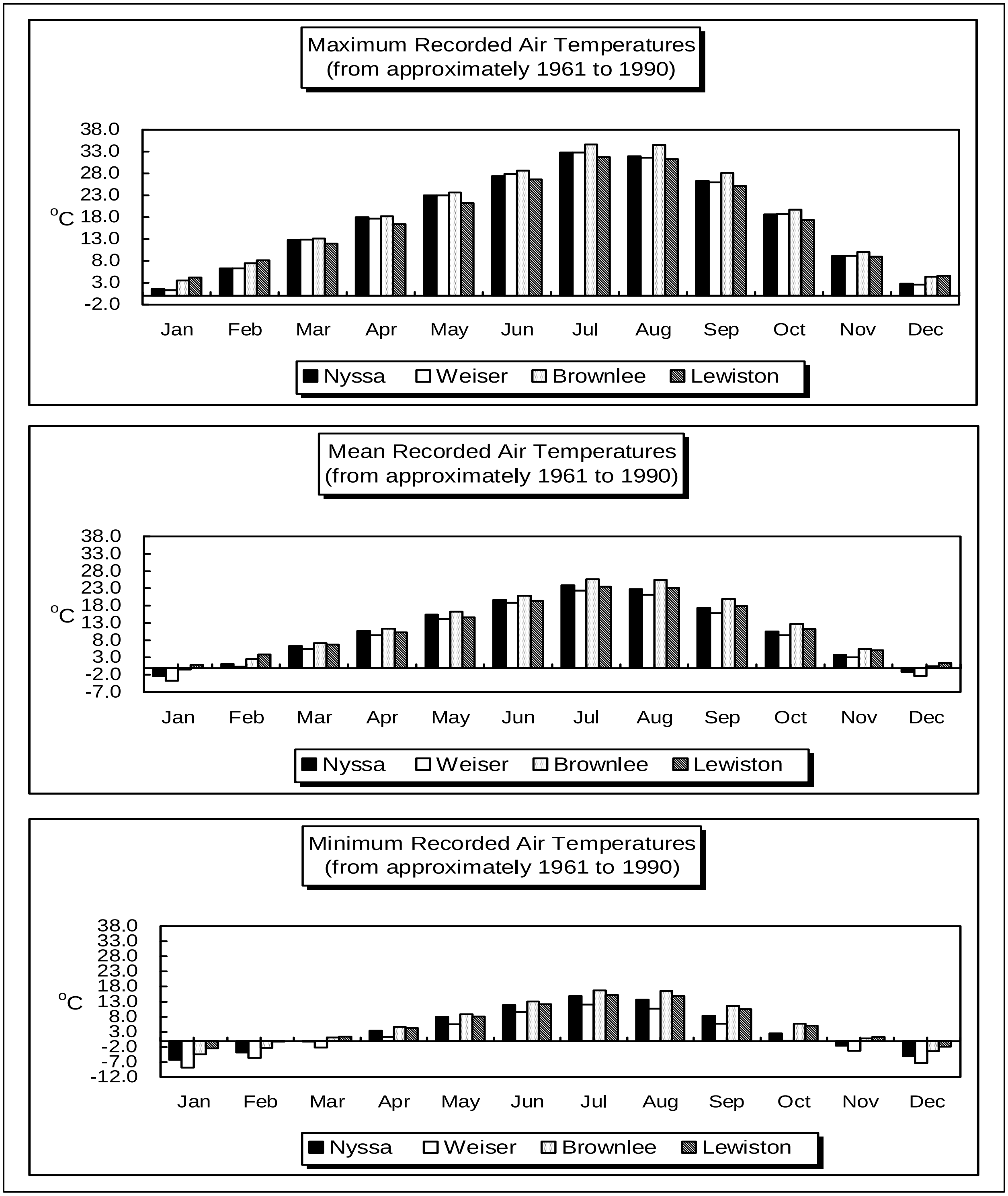

Figure 2.1.3 Air temperatures observed at four locations in the Snake River – Hells Canyon area between 1961 and 1990 (Nyssa at RM 385, Weiser at RM 351, Brownlee at RM 285 and Lewiston, downstream of the TMDL reach, at RM 139).

Photo 2.1.0. Ice accumulation on the bank of the Snake River near Ontario, Oregon (near RM 369) circa 1939 to 1940, relatively low water years. Photo from the collection of Dr. Lyle M. Stanford.

Flora and Fauna

The flora of the SR-HC TMDL reach of the Snake River is dominated by shrubland vegetation communities (approximately 42.7% of the total area) with a narrow strip of riparian vegetation (0.1% of the total area) along the river and reservoirs. Approximately 2.2 percent of the area is non-vegetated (water or barren slopes and cliffs) and about 10.4 percent is used for agricultural purposes (crops and grazing). Grassland areas make up the majority of the remaining land area (15.9% total). Upland vegetation communities are primarily grasslands, shrublands and shrub-savanna assemblages. Riparian vegetation is primarily scrub-shrub wetlands and shore and bottom-land communities. Nearly 71 percent of the total area is either shrub or forested land. See Figure 2.1.4 (USGS, 2000a).

There is a large diversity of fauna that inhabits these vegetation communities. Large game animals include (among others) black bear, antelope, mule and white tail deer, elk, bighorn sheep, mountain lions and mountain goats. In addition there are a number of smaller mammals including coyote, mink, otter, badger, red fox, and beaver.

A wide variety of birds use the upland vegetation including western meadow larks, valley and mountain quail, western kingbirds, lark sparrows, mourning doves, Brewer’s blackbirds, lazuli buntings, spotted towhees, brownheaded cowbirds, Bullock’s orioles, black billed magpies, chukars and rock wrens. The riparian vegetation is also used by many species including lazuli buntings, spotted towhees, blackcapped chickadees, yellow breasted chats, cedar waxwings, warbling vireos, blackheaded grosbeaks, black billed magpies, song sparrows, western tanagers and red-eyed vireos. The river and reservoirs provide food for a number of other birds including great blue herons, bald eagles, and a variety of geese, ducks and gulls (IMNH, 2002, Audubon, 1997).

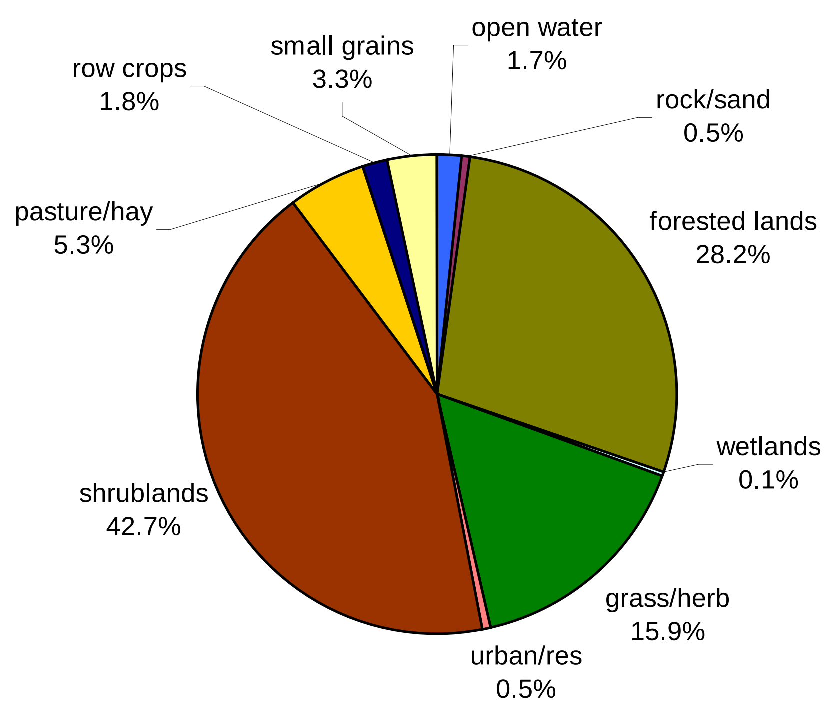

Figure 2.1.4 Relative percent land cover in the Snake River – Hells Canyon TMDL reach.

This reach also provides habitat for many reptile and amphibian species and a large variety of invertebrates. Amphibians in this reach of the Snake River include spadefoot, western and Woodhouse's toads; longtoed salamanders; Pacific tree, spotted and tailed frogs; and bullfrogs (IMNH, 2002, Audubon, 1979). Bullfrogs are an exotic (introduced) species in this area and have caused problems and decline in native populations. Reptiles in this reach include painted turtles, collared lizards, horned lizards, leopard lizards, sagebrush lizards, fence lizards, side-blotched lizards, whiptails, boas, racers, night snakes, gopher snakes, longnose snakes, ground snakes, garter snakes, and rattlesnakes (IMNH, 2002, Audubon, 1979). Invertebrates in this reach include the Idaho springsnail (*Pyrgulopsis idahoensis,* formerly *Fontelicella idahoensis*), identified in the region between RM 422 and 393 and between RM 372 and 366; and the Bliss Rapids snail (*Taylorconcha serpenticola*), identified in the region between RM 228 and 225 and in several areas of the Snake River upstream of the SR-HC TMDL reach. Both of these snail species are listed as threatened under the Federal Endangered Species Act (ESA).

Fisheries
The free-flowing segments of the Snake River and the reservoirs within the SR-HC TMDL reach are home to several native and non-native fish. The native fish that use the river and reservoirs include bull trout and redband trout, northern pike minnow, large-scale and bridgelip suckers, mountain whitefish and white sturgeon. Adult bull trout use the river and reservoirs in and below Hells Canyon Reservoir and its tributaries (RM 272.5 and downstream), with the documented use of Hells Canyon Reservoir being extremely limited. Bull trout are present in the Powder River Basin above Thief Valley and Mason Dams. These populations are not expected to utilize the SR-HC TMDL reach of the Snake River (personal communication, Jeff Zakel, ODFW, 2002). Bull trout are listed as threatened under the ESA. Non-native fish present in the SR-HC TMDL reach include large and small mouth bass, yellow perch, blue gill, black and white crappies, four species of catfish and common carp as well as hatchery rainbow trout. The river and its tributaries below Hells Canyon Dam also provide habitat for the Snake River fall and spring/summer chinook as well as steelhead, all of which are listed as threatened under the ESA. Historically the Snake River also provided passage and habitat for coho salmon. This evolutionarily significant unit (ESU) was declared extinct in 1986.

2.1.1.2 GEOLOGY

The Snake River drains parts of two major geological landforms within the Columbia Intermontaine province: the eastern half of the Central Mountains, and the north central part of the High Lava Plains, principally the Malheur-Owyhee Upland. Hells Canyon, the portion of the

Photo 2.1.1. Arial view of Hells Canyon area, pre-construction of the Hells Canyon Complex of dams, circa 1939 to 1940. Photo from the collection of Dr. Lyle M. Stanford.

reach below Hells Canyon Dam, drains out of the Central Mountains that include the Blue, Wallowa and Seven Devils mountain ranges. These mountains are a complex group of folded and faulted uplifts that reach elevations of 6,000 to 10,000 feet. Hells Canyon is 8,000 feet deep at its deepest and averages 5,500 feet in depth for 50 miles of its length.

The canyon walls include rocks from the Permian period through the Cretaceous period that were folded and faulted, and then intruded by granitic batholiths. These were eroded and then covered by a number of basaltic lava flows during the Miocene epoch. The area then was raised and the canyons cut by the eroding activity of the rivers. Most of the exposed rocks in Hells Canyon are the dark-colored Miocene basalts of the Columbia River basalt group (Orr *et al.*, 1992).

Near Brownlee Dam the Cuddy Mountain fault intersects the Snake River (Mann, 1989). This fault is still active and several small earthquakes have been detected in the vicinity of the fault. At the oxbow where Oxbow Dam is located there is evidence that the ancient Snake River broke through a divide and captured a south flowing river during the Pleistocene epoch. From this point upstream, past the end of the SR-HC TMDL reach, the Snake River drains mainly the Malheur-Owyhee Upland which is considered either to be part of the High Lava Plains (Rosenfeld, 1993) or part of the Basin and Range landforms (Orr *et al.*, 1992). This is an area underlain by Cenozoic lava flows that have subsequently been covered by thick ash and alluvial deposits.

The area upstream of the SR-HC TMDL reach is geologically rich in phosphorus. A 1974 inventory of the nations waters (US EPA, 1974a) found that the mountains along the southeastern border of the Snake River, which form its headwaters, contain some of the world's richest phosphate deposits.

2.1.1.3 SOILS

Most of the soils in the SR-HC TMDL reach of the Snake River fall into one of two soil orders: Mollisols or Aridisols (Jones, 1993). Mollisols are well-developed soils with organic-rich surface horizons and that are rich in basic cations such as calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}) and sodium (Na^{+}). Xerolls are the most common suborder of the Mollisol soils within this reach. These soils develop in moist winter/dry summer climates, and are continually dry for long periods of time. These soils dominate the steppe and shrub-steppe vegetation areas in the reach. Aridisols are soils that occur in dry areas. These soils tend to be low in organic matter and are typically light in color. The two most common Aridisols in this reach are those with accumulations of calcium carbonate and other salts (Orthids) and those that are distinguished by the accumulation of clay in the subsurface horizons (Argids). The latter are typical to the Snake River plain at the upstream end of the SR-HC TMDL reach.

The Bonneville Flood, a catastrophic flood event that occurred approximately 14,500 years ago as the result of the failure of one of the natural dams at Red Rock Pass of Pleistocene Lake Bonneville, deposited fine-grained silty soils over much of the region. Pleistocene Lake Bonneville covered most of Utah and parts of Idaho. During the flood event, approximately 25 million cubic feet of water per second moved down what is now the Snake River Canyon. The floodwaters eroded the canyon to over 500 feet deep and a mile wide in some places. The results of this erosion are visible today in the large bar complexes, fine-grained, easily re-suspended slack water deposits, scoured and eroded basalt and scabland topography in the SR-HC TMDL reach (Link *et al.*, 1999).

2.1.1.4 HYDROLOGY

Surface Water

Flows.

The Snake River is a highly regulated river, with the first dams constructed nearly a century ago, primarily to provide irrigation water supply. Available estimates indicate that nearly half the annual discharge of the Snake River is stored and diverted for irrigation upstream of the Hells Canyon Complex of dams (usable storage capacity above Hells Canyon is ~10 million acre-feet, average annual runoff at Weiser, ID of 13.25 million acre-feet). With such a highly regulated system it is difficult to determine what are natural conditions, or precisely how altered are current conditions from natural.

Because of the extensive flow regulation within the Snake River system, late summer and early fall flows into the Hells Canyon Complex are typically greater than they were before flow regulation began. While no flow data exists prior to the beginning of diversion for irrigation within the Snake River system, the period prior to completion of American Falls Dam in 1926 is one of relatively unregulated flow. By 1956, with completion of Palisades and Lucky Peak Dams, all major storage above the City of Weiser, Idaho was completed. Snake River flow at Weiser for these two time periods is compared in Table 2.1.0.

Table 2.1.0 Comparison of historical (1911 to 1926) and recent mean Snake River flow at Weiser, Idaho.

Mean cfs	June	July	Aug	Sep	Oct
1911 to 1926	36,155	14,138	7,691	8,947	13,925
1956 to 2001	23,692	11,626	10,779	12,970	14,962
%Diff	-34%	-18%	+40%	+45%	+7%

Though there are many dams on the Snake River, most of them on the river itself are what are known as “run of the river” impoundments, and do not store much water. Major storage reservoirs include Palisades Reservoir, American Falls Reservoir, Lake Walcott, and Brownlee Reservoir. The first three are several hundred miles upstream of the SR-HC TMDL reach. Furthermore they are above Milner Dam (RM 639), where practically all water is diverted for irrigation from July through September, often longer. Below Milner Dam the Snake River is replenished by springs and extensive surface water return flows, rapidly gaining volume, and averaging 15,700 cfs at Weiser, Idaho (RM 351), 16 miles upstream of Brownlee Reservoir.

As evidenced by the information above, flows in the SR-HC TMDL reach are heavily influenced by water resource development and management within the reach and upstream in the Snake River and in the tributaries. This development provides irrigation water supplies for more than 3.5 million acres of irrigated lands upstream of Brownlee Dam. The average annual flow of the Snake River at Brownlee Dam is about 14 million acre-feet. The USBR (1997) estimates that between 14.5 and 16.5 million acre-feet of water are diverted from streams and between 3.5 and 7.5 million acre-feet are pumped from ground water in the basin upstream of Brownlee Dam. About 8.5 million acre-feet is estimated to return to the rivers or aquifers for a total annual consumptive use from surface diversions of between 6 and 8 million acre-feet (USBR, 1998). However there are minimum flows (3,300 cubic feet per second (cfs) at the Murphy gage, and 4,750 cfs at the Weiser gage) adopted for the SR-HC TMDL reach by the Idaho legislature (Idaho State Water Plan, 1996).

Due to differences in tributary inflows, diversions and interactions with underlying aquifers, the average annual flow of the Snake River varies widely by location and year. It is therefore important to specify a period of record when discussing surface hydrology in this basin. In the following sections, different periods of record are used depending on the available information, however each period is appropriately identified when it is used. Data available from the USGS gauge near the Weiser River inflow in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach reflect most of the water management upstream of Brownlee Reservoir, including tributaries, reservoirs, ground-water discharge and irrigation return flows to the mainstem Snake River.

For the period of record 1911 – 1999, Snake River flow data at Weiser, Idaho show an average seasonal variation from 9,829 cfs in August (low) to 28,690 cfs in May (high) (Brennan *et al.* 1999). In contrast, average flow data from the USGS gauge immediately below Hells Canyon Dam (period of record 1966 – 1999) show 11,560 cfs in August (low) to 30,950 cfs in April (high). These data suggest a slight increase in base summer flows, likely attributable to tributary inflows, leaving the Hells Canyon Complex reservoirs as compared to that entering Brownlee Reservoir at Farewell Bend. Also, the peak flows below Hells Canyon Dam are shifted slightly earlier in the spring (April) than peak flows at the Weiser Gage (May). While the magnitude of the peak flow from Hells Canyon Dam is higher than the peak flow at Weiser, this can also be attributed to tributary inflows between the two monitoring locations. Comparisons of the two locations for the same period of record show similar results. The average outflow of the Snake River at Hells Canyon Dam is about 14 million acre-feet per year, which closely matches the average annual inflow at Brownlee Dam.

Major tributaries to the SR-HC TMDL reach are the upstream Snake River mainstem flowing into the reach at RM 409, the Owyhee River (RM 396.7), the Boise River (RM 396.4), the Malheur River (RM 368.5), the Payette River (RM 365.6), the Weiser River (RM 351.6), the Burnt River (RM 327.5), the Powder River (RM 296), and the Imnaha River (RM 191.6).

Flows within the Snake River system are strongly seasonal. The majority of in-river flow is a result of snowmelt and runoff from those areas of the watershed where precipitation falls mostly as snow, although ground water does represent a substantial source in some areas. Snowmelt-driven flow regimes commonly result in low flows during the fall and winter months and high flows during the spring and early summer months. The total volume and timing of surface runoff is highly variable from year to year. In the upstream drainage areas of the major tributaries to the SR-HC TMDL reach, ground-water discharge to streams is generally fairly constant throughout the year, but varies somewhat from year to year depending on the relative level of annual precipitation and the duration and timing of snowmelt.

Annual discharge is also highly variable. During the 1928 to 1996 hydrologic period, the annual discharge of the Snake River at the Weiser gauge varied from a high of 24.5 to a low of 6.4

million acre-feet (1971 and 1934 respectively). The annual flow of the Snake River near Weiser was greater than 19 million acre-feet 10 percent of the time and greater than 8.1 million acre-feet 90 percent of the time (USBR, 1998) for this period of record.

Table 2.1.1 Range of flows in the Upstream Snake River segment of the Snake River - Hells Canyon TMDL reach (RM 409 to 335).

Inflow[1]	Gauge Location	Mean Annual Flow (cfs)	Average Summer Flow[2] (cfs)	Low Flow (cfs)	USGS Gauge #	Comments[3]
Mainstem Snake River	Murphy, Idaho, upstream of RM 409	9,577	8,529	4,370 (06/1992)	13172500	
Owyhee River (RM 396.7)	None (Closest gauge is near Rome, Oregon)	436	438	56 (08/1992)	13181000	*Inflow value calculated by USBR (2001) because gauge is above Owyhee Reservoir
Boise River (RM 396.4)	Near Parma, Idaho	1,349	1,496	82 (04/1987)	13213000	
Malheur River (RM 368.5)	Near Vale, Oregon	382	357	11 (09/1994)	13233300	*Inflow value calculated by USBR (2001) because gauge is well upstream of mouth
Payette River (RM 365.6)	Near Payette, Idaho	2,693	2,903	127 (08/1991)	13251000	A one-time flow of 32,000 cfs was recorded during a rain-on-snow event in Jan. 1997
Weiser River (RM 351.6)	Near Weiser, Idaho	1,100	840	34 (10/1988)	13266000	A one-time flow of 31,000 cfs was recorded during a rain-on-snow event in Jan. 1997
Mainstem Snake River	Near Weiser, Idaho RM 351.6	15,714	14,526	4,460 (06/1992)	13269000	A one-time flow of 82,000 cfs was recorded during a rain-on-snow event in Jan. 1997

[1] River miles in this column refer to the Snake River Mile (RM) at the inflow of the named tributary.
[2] Summer season is defined as May through September
[3] This precipitation event produced singular, extreme high flows that were well outside of the general range observed over the period of record (1980 to 1999).
* USBR calculated flows from 1991 to 1992 and 1997 to 1998 were used to calculate the average flows at the inflow to the SR-HC TMDL reach (USBR, 2001).

The operation of the reservoir system for flood control and for flow regulation is also a significant factor in the shaping of mainstem flow patterns. The Hells Canyon Complex reservoirs are operated primarily for hydropower. In addition, they are currently operated to control and store runoff (Brownlee Reservoir only, under US Army Corps of Engineers direction), to accommodate spawning and migration of anadromous fish (below Hells Canyon Dam only), to support navigation (below Hells Canyon Dam only) and to support recreation. It should be noted that these various functions of the complex can be contradictory, which sometimes leads to fulfilling one mission at the expense of another. Tributary reservoir systems are operated, for the most part, to control and store runoff and to release storage during the irrigation season. These operational constraints on both the tributary and mainstem systems overlie the natural runoff pattern and alter natural streamflow patterns.

Impoundments.

Mainstem flow within the SR-HC TMDL reach is heavily controlled by dams and other water-control structures on both the mainstem (upstream) and inflowing tributaries. It is estimated that less than 20 percent of the total inflow from the Snake River watershed reaches the mainstem river without first passing through a reservoir or other flow-control structure (USBR, 1998). This high level of management affects both the magnitude and timing of flow variations within the mainstem Snake River. Current high flows are usually not as high as those recorded in the early 1900s and in some areas average low flows are not generally as low as those recorded prior to the placement of impoundments. Although the average volume of water flowing through the river system on an annual basis may not have changed substantially over time, the water volume now tends to be more evenly distributed over the year. Increased spring flows still occur, but are spread out over longer intervals and tend to peak at flow values lower than those recorded historically (USBR, 1998; USGS, 1999). In addition to the stabilization in flow from upstream impoundments, the calculated consumptive use of legal, state-authorized agricultural diversions within the SR-HC TMDL reach equates to approximately 35 percent reduction in flow (average).

The upstream impoundments themselves also have an observable effect on pollutant transport within the basin. Pollutants associated with increased flow volumes and high velocities (i.e. sediment, mercury and pesticides) are not distributed as randomly as they would be in a more free-flowing system. Instead, they tend to accumulate behind structures such as dams and diversions. While this reduces the overall concentration of such pollutants downstream, it localizes the pollutant mass and can lead to significant pollutant releases if water-management practices in the impoundments result in substantial drawdowns. It can also lead to conditions where designated beneficial uses are negatively affected by a reduction in a given constituent such as sediment. Sediment tends to accumulate behind structures and in their reservoirs, resulting in less than optimal spawning habitat due to cobble-embeddedness (too much fine sediment upstream) in flowing river systems with redd-spawning fish species. Cobble embeddedness is generally not a major issue with reservoir spawning fish since they typically are broadcast or nest spawners rather than redd-spawners. Reservoir spawning fish generally do not deposit eggs in the substrate. Hydraulic conditions in low velocity areas (such as reservoirs) are not conductive to intergravel egg survival. In-reservoir sediment deposition can lead to reduced availability of gravel-sized particulates downstream that may in turn reduce available spawning habitat for downstream fish species.

Dams and related structures can also result in changes in flow velocity and timing that can affect designated beneficial use support through changes in the transport and processing of nutrients and algae. Reduced velocities can lead to conditions where excessive incoming nutrient and organic loads, delivered to an impoundment, result in nuisance algal growth and dissolved oxygen depletion. These blooms, in combination with delivered organic loading can lead to increased oxygen demand in the lower layers of the reservoir system. Reduced dissolved oxygen concentrations created by the elevated oxygen demand can, in turn, lead to a reduction in suitable aquatic habitat, fish kills, and increased nutrient and toxics release at the sediment/water interface. In this manner, impoundments can act to increase the sensitivity of the river system to incoming nutrients and algal loading (also described as a reduction in assimilative capacity).

Additional potential effects of impoundments on pollutant fate and transportation include increased opportunity for methylation of mercury, increased surface water temperatures due to increased surface area and decreased flow rates, cooling effects on impounded volumes, opportunities for the creation/release of ammonia, hydrogen sulfide, metals and phosphorus from bottom sediments, and thermal stratification leading to anoxia/hypoxia below the thermocline. Not all of these occur in all reservoir systems, and not all occur at the same rate or intensity. The influences of the reservoir systems within the SR-HC TMDL reach are discussed in more detail in the following sections and in the pollutant-specific loading analyses.

While many of the above processes can result in reduced water quality, impoundments can also act to improve some aspects of water quality in downstream segments. Reservoirs often act as a sink for both sediment and nutrients, reducing delivered loads downstream, and can reduce summer water temperatures through deep-water releases. However environmental management for preventing pollution before it enters the waterways rather than depending on instream treatment is preferred by the US EPA, IDEQ and ODEQ.

Ground Water

Significant amounts of ground water (about 250 million acre-feet in the top 500 feet of substrate) are found in the Snake River Plain Aquifer system (SRPA), one of the largest ground-water systems in the United States (USBR, 1998). The western portion of the SRPA underlies the SR-HC TMDL reach between RM 409 and roughly RM 340). This section of the SRPA covers about 4,800 square miles and is composed primarily of sedimentary deposits of silt, clay, sand and gravel with basalt interflows. Aquifers in the drainage areas tributary to the Snake River provide ground water for use within the individual drainage areas. These also provide varying amounts of recharge to the SRPA, in the form of subsurface ground-water inflow, (USBR, 1998).

While shallow ground water (subsurface recharge) in the SR-HC watershed is more easily influenced by agricultural and stormwater pollutants, deep ground water in the SR-HC watershed is commonly of high quality, suitable for drinking, agriculture, and industrial uses. Deep ground-water quality is often better than that required to meet national drinking water standards. However, while there are exceptions in some cases where concerted efforts have been made to prevent or reverse negative impacts (Shock *et al.,* 2001), general ground-water quality trends in the SR-HC watershed indicate an increasing occurrence of nitrate contamination in areas of intense ground-water usage (ODEQ, 2000b; NRCS, 2000; IDEQ, 1985, 1986, and 1988a).

Contamination from both point and nonpoint source activities has occurred, however, it is generally localized, ranging from a few acres up to several square miles. The most common point sources of ground-water contamination are above- and below-ground petroleum storage, leaks and accidental spills of industrial chemicals, and land application of wastewater.

Nonpoint sources of ground-water contamination are difficult to identify and assess due to limited monitoring data. Potential nonpoint sources include agriculture, septic systems and urban runoff. Shallow ground water (subsurface recharge) has also been found to contain high concentrations of phosphorus (USDA and USGS monitoring). Agricultural chemicals can reach ground water in significant quantities under conditions of high soil permeability, chemical mobility, and inappropriate water application practices. While high nitrate levels in some areas have been observed, the limited data available for agricultural pesticides in ground water has not shown levels that pose a public health threat. Septic systems can impact ground water when the water table is shallow, soil conditions are inappropriate or system density is excessive. Little site-specific data is available on septic-based effects on ground water in this area. Impacts from infiltration of urban runoff in this area are also poorly investigated. With appropriate placement, management and control programs in place, these nonpoint source effects can be minimized or removed in many cases (USBR, 1998; NRCS, 2000; IDEQ, 1988a).

Within the Snake River Basin, surface and ground-water systems are interconnected. Changes in ground-water recharge or discharge have been observed to affect surface water flows (IDEQ, 1988a). Similarly, infiltrating water from irrigation systems and stream flows represent a significant portion of the ground-water budget (USBR, 2001). At many places in the basin, the Snake River channel is above the regional water table and instead of the aquifer discharging to the river, the river recharges the underlying aquifer (USBR, 1998). In low-water years, pumping and diversions can remove more water from the Snake River than is contributed by some of the inflowing tributaries. Irrigation recharge during periods of low tributary input represents a significant source of in-river flow (as much as 52 percent (IDWR and ODWR, water supply data)).

2.1.1.5 TEMPORAL VARIATIONS

Many changes have occurred in the Snake River Basin over the course of historic time. While a detailed assessment of these changes would require extensive volumes of text and is therefore impossible to include within the scope of this document; the following sections attempt to capture these changes and their effects on the SR-HC system in a general sense. Separate discussions of changes in pollutant loading over time, or violations of water quality standards are included in those sections specific to pollutant assessment and loading.

2.1.1.6 SUBWATERSHED AND TRIBUTARY CHARACTERISTICS

Over 95 percent of the average total mainstem flow in the Snake River system within the SR-HC TMDL reach is from direct tributary inputs. The tributary inflows to the SR-HC TMDL reach include the Snake River upstream of the SR-HC TMDL reach (inflowing at RM 409). Tributary flows can be ranked according to relative average annual inflow as follows: the upstream Snake River (55.8 %), the Payette River (15.7 %), the Boise River (7.9 %), the Weiser River (6.4 %), the Owyhee River (2.5 %), the Malheur River (2.2 %), the Powder River (1.4 %) and the Burnt

River (0.5 %). These inflowing tributaries routinely exhibit highly variable annual flows (Table 2.1.1). Ungaged flows make up approximately 7.5 percent of the total flow volume.

2.1.2 Cultural Characteristics

2.1.2.1 Land Use and Ownership - Historical and Current

Tribal Use

The majority of the SR-HC TMDL reach is located within most of the Nez Perce Tribe's ceded territory as documented by the Indian Claims Commissions in Docket No. 175. In the Treaty of 1855, the Nez Perce Tribe retained numerous rights that extend into the ceded territory and beyond. These include the right to take fish at all usual and accustomed places, the right to gather roots and berries, the right to hunt on all open and unclaimed lands and the right to pasture horses and livestock. These rights have been upheld by federal courts and have given the Tribe co-management authority in some areas.

The Snake River and Hells Canyon are of vital importance to the Nez Perce Tribe. This area has been utilized by the Tribe since time immemorial for salmon, sturgeon and lamprey fishing, the gathering of ceremonial, medicinal and food plants, hunting, and spiritual and ceremonial use. These uses continue today. The economic, social, and spiritual health of the Tribe is in part derived from a healthy Snake River ecosystem.

Agriculture and Grazing

Agriculture in the Snake River Basin surrounding the SR-HC TMDL reach includes both irrigated and non-irrigated uses; the latter includes crop production, animal feeding operations (AFOs) and open range grazing. No quantitative information is available on the level of irrigated agriculture in the Snake River Basin preceding the arrival of white settlers.

With the advent of white settlement in the region, irrigation practices became widespread and intensive. During this period (mid 1800s to the early 1970s), impoundment and diversion of the Snake River and tributary waters increased significantly. From early settlement to the late 1960s and 1970s, the predominant irrigation practices included furrow, sub-flood and flood irrigation techniques. In the first two cases, water is diverted from a larger surface water supply (creek, canal, ditch, etc.) and allowed to move laterally down a secondary ditch or furrow, saturating the adjacent soil. In flood irrigation, water is allowed to move across the top of the soil in a sheet and saturation occurs from the surface downward. During the 1960s and 70s, sprinkler systems were constructed in many areas of the Snake River Basin, allowing lands that were previously not irrigated due to elevation or location to be brought under irrigation. Furrow, flood and sub-flood, sprinkle and drip irrigation methods continue to be used in many areas of the basin.

Irrigated agriculture accounts for over 95 percent of all out-of-stream water diversions and ground-water pumping in the Snake River basin. Of the 3.5 million acres of irrigated land upstream of Brownlee Dam, about 2 million acres are supplied by surface water, mostly by gravity diversions (USBR, 1998).

An estimated 14.5 to 16.5 million acre-feet of surface water are annually diverted and conveyed by more than 3,000 miles of canals and laterals to irrigated fields (IWRB, 1996; USBR, 1997).

Of this amount, gravity diversions from the Snake River (mainstem) total about 9.5 million acre-feet, while gravity diversions from tributaries are about 6 million acre-feet and pumpage from the mainstem and tributaries is about 1 million acre-feet. In addition, another 3.5 to 7.5 million acre-feet of ground water, mostly from the upper Snake River basin, is supplied annually to agricultural lands. Total out-of-stream diversions and ground-water pumpage averages about 20.5 million acre-feet per year. Most of the diverted water returns to the stream or aquifer; consumptive use of surface diversions is calculated at between 6 and 8 million acre-feet (USBR, 1997 and 1998; Idaho State Water Plan, 1996).

Over 95 percent of ground-water withdrawals in the Snake River basin are used for irrigation. Ground water pumping represents between 19 and 30 percent of the total agricultural water requirements depending on the water year and local seasonal variations. Under average conditions, ground-water pumping accounts for approximately 25 percent of the total agricultural requirements. Ground water is also used to meet virtually all domestic, public supply, and industrial requirements in the Snake River Basin (USBR, 1998).

The increase in agricultural land use that has occurred in the SR-HC TMDL reach since early settlement has resulted in increased pressures on surface and ground-water quality. In some areas of the drainage, nitrate and phosphate levels in ground water have increased with the application and improper handling of agricultural fertilizers. In addition agricultural pesticides have been detected in ground water in some areas of the drainage (NRCS, 2000; IDEQ, 2000c; Hedley *et al.*, 1995; US EPA, 1986a; ODEQ, 2000b). Recently however, a concerted effort has been undertaken in many areas of the drainage to reduce the negative impacts of past practices and restore water quality. Many cropping and grazing practices have been, and are being improved specifically with water quality in mind (IDEQ, 1998a; IDEQ, 1999b and 1999c; Malheur Co., 1978, 1981, 2000; MRBLAC, 2000; MOWC, 1999). Riparian restoration and grazing and irrigation management improvements are being applied on a voluntary basis in many areas. While these projects cannot promise instant improvements in water quality, over time concerted efforts are showing positive results.

Mining
The SR-HC TMDL reach of the Snake River has been the site of a number of mining activities, mostly for gold, silver and mercury ores. Gold was mined in the Central Mountain landform particularly in the Blue, Seven Devils and Wallowa Mountains but also along the banks of the Snake River itself. Gold, silver, uranium, bentonite (volcanic ash) and mercury were mined in the Owyhee uplands and Malheur County. Silver City, Idaho, (Photo 2.1.2) located in the Jordan valley area of the Owyhee River watershed, was the site of a major historic silver mining operation. Much of the mercury used for amalgamation of the mined silver and gold was mined just outside the Owyhee watershed (Idaho) in the Opalite mining district near the McDermitt caldera in southeastern Oregon. Most of the mines have not been operational since the 1950s or 1960s but there are occasional, usually small, mining activities currently in place. Mercury deposits have also been identified in the Weiser River drainage (IDEQ, 1985), although mining activities in this drainage were more limited in scope.

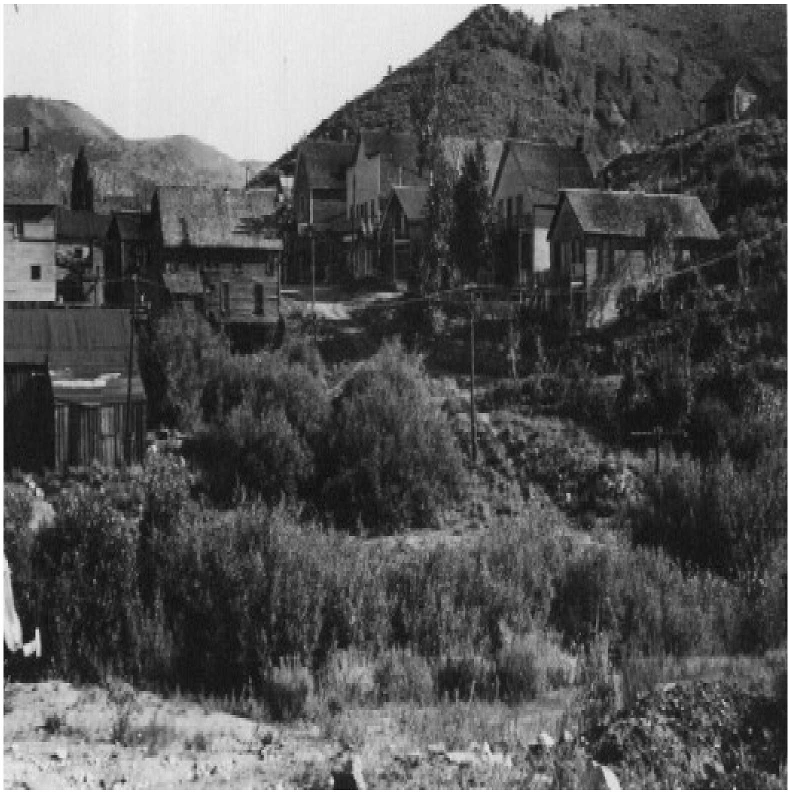

Photo 2.1.2. Historic mining town of Silver City, located in Owyhee County, Idaho, circa 1938. Photo from the collection of Dr. Lyle M. Stanford.

Historically, dredge mining occurred on many sections of the Boise River, a tributary to the Snake River. Some lode and other forms of placer mining also occurred. Most of the historic mining in this drainage occurred on the Middle and South Fork of the Boise River and its tributaries near Atlanta and Idaho City (Middle Fork Boise River), and the Featherville-Rocky Bar area (South Fork Boise River). Currently, the largest mining district within this drainage is the Atlanta district. Historic production is estimated at 400,000 ounces of gold. Other old mines in the area include an antimony mine near Swanholm Peak (Middle Fork Boise River), and some small gold and silver base-metal mines in tributaries to the Boise River. Recreational mining also occurs in this area with small suction dredges. Operators are regulated by permits and rules issued by the Idaho Department of Water Resources (IDWR).

Urbanization

Both Oregon and Idaho have been predominantly rural from their initial settlement until the fairly recent past (~1960). Original territory and later state economies were based on agriculture (both livestock and irrigated croplands), timber and mining. Over the last 30 years, significant population increases have occurred. Although the majority of population growth has been centered primarily between the municipalities of Boise, Idaho and Ontario, Oregon, many areas within the scope of this TMDL and its tributary drainages have experienced a noticeable shift from agricultural-based land use to more urban/suburban land use. This trend is occurring to a greater degree in southwestern Idaho than in southeastern Oregon. As with the expansion of agricultural land use discussed earlier, increasing urbanization of the SR-HC TMDL reach has also resulted in increased pressures on environmental quality.

Urban/suburban runoff from impervious surfaces and roadways, lawn-based fertilizers and pesticides, poorly treated effluent from failing or improperly functioning septic and sewer systems, and many other factors have negatively affected both ground and surface-water quality (IDEQ, 1998a, 2000c; Arnold and Gibbons, 1996; Chandler, 1994). Significant efforts have been undertaken on the part of both municipalities and rural subdivisions to improve both air and water quality. In particular, advancements in wastewater treatment and stormwater treatment have resulted in reductions in loading to surface water systems over the past two decades.

Recreation
Recreation within the SR-HC TMDL reach historically included many of the same opportunities available today although at a much lower intensity and potential for negative impacts on water quality. Accounts detailing recreational boating, fishing, hunting, swimming and camping are

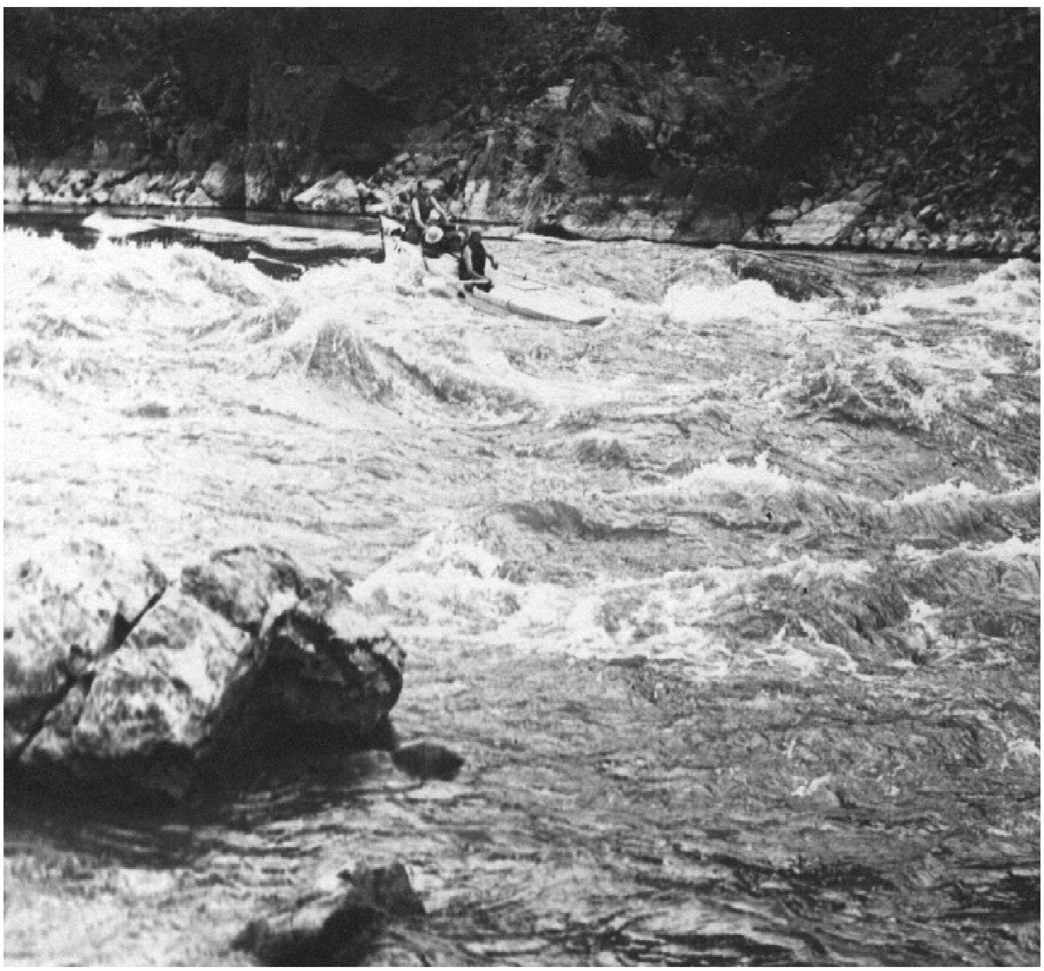

Photo 2.1.3. Running Steamboat Rapids in a rigid craft, circa 1939 to 1940. Front boatman is identified as Horace Parker. Photo from the collection of Dr. Lyle M. Stanford.

plentiful from the time of the first recorded contact with the area by both native peoples and the white settlers who came later. Early recreational use was limited by accessibility and flow in some areas, but continued to grow as the local population increased.

Construction of improved access roadways and the construction and operation of the Hells Canyon Complex reservoirs have changed both the level and type of recreational use in the area. Use intensity has increased dramatically and motorized craft have replaced other more primitive forms of boating to a large degree. Currently the SR-HC TMDL reach contains many locally, state-wide and nationally recognized recreation opportunities including the Hells Canyon National Recreation Area, national forests, state and local parks, specially designated recreation areas, wildlife refuges and trophy fisheries. This wide variety of recreation opportunities available to visitors and area residents adds to both the quality of life and the local economy.

Most, if not all, of these recreational opportunities are directly dependent on water quality in one form or another (i.e. salmon fisheries require water quality adequate for cold water aquatic life while bass fisheries require water quality adequate for warm water aquatic life). Activities such as fishing, swimming and boating depend on the attainment of water quality standards for safety in contact recreation and for adequate habitat for aquatic life. Somewhat less obvious is the link between recreational activities such as hunting, hiking or camping and water quality. However, wildlife habitat, and forest and riparian area health can be directly affected by water quality. Water also provides an aesthetic component to many land-based activities that do not require a body of water but are generally enhanced by association with water (USBR, 1998). Operational and flow management conditions can also have a significant effect on recreational uses. Both direct usage and local economies may be affected to a noticeable degree by water quality and water quantity management practices. Some recreational opportunities are described in more detail below.

<u>Boating.</u>
Boating is one of the most popular water-dependent recreation activities in the SR-HC TMDL reach. The type of boating activities varies with the type of water in each segment of the reach. Boating use is significant in both the riverine (upstream and downstream of the reservoirs) and the reservoir sections of the SR-HC TMDL reach. Overall boating use (upstream, downstream and in-reservoir) has increased with the completion of the Hells Canyon Complex reservoir system. The reservoirs provide numerous flat-water recreation opportunities that include water-skiing, cruising and fishing. These activities are normally enjoyed early in the recreation season when reservoirs are full. Reservoir drawdown and low river flows in the late recreation season often limit these activities due to decreased boat access resulting from low water levels. If drawdown and low river flows occur during the peak recreation season, these activities may be curtailed depending on the magnitude and duration of the drawdowns (USBR, 1998). Non-motorized boating, such as sailing and canoeing are also popular in the SR-HC TMDL reach, but represent a smaller percentage of overall boating activity on reservoirs than motorized boating. In contrast, kayaking, canoeing, and scenic and white-water rafting are the most popular boating activities on the free-flowing Snake River below Hells Canyon Dam and on tributary streams. However, motorized boating does occur in some tributary reaches.

Fishing.
Fishing is also a popular recreation activity on the river system and provides an important boost to local economies. Fishing activity peaks in early summer after the spring runoff and remains high through October. A high percentage of summer fishing on reservoirs is boat fishing, but there are also opportunities for shoreline fishing (USBR, 1998). Game fish species present in the SR-HC TMDL reach include bass, catfish, crappie, white sturgeon, salmon, steelhead, and rainbow trout. Fishing on the reservoirs can be affected directly due to the boat access issues cited above or indirectly due to the effects of reservoir levels on reservoir fish populations by fluctuating reservoir levels. The critical time for nesting by such resident fish as small mouth bass and crappie is from May 1 to June 30. Drawdowns and refilling during or near spawning periods for resident warm water fish in reservoirs can cause lowered spawning success rates. Fluctuating water levels decrease the amount of suitable spawning, early emergence and early rearing habitat for resident fish.

Wildlife and Hunting.
As with fishing, hunting and viewing wildlife is a popular recreational activity in the SR-HC TMDL reach. Important wildlife that are hunted or trapped in the area include bear, coyote, otters, mink, deer, Rocky Mountain wild sheep, mountain lions, elk and a multitude of birds. There are established hunting seasons for a number of these animals as well as for various types of waterfowl and upland birds in the fall and winter months.

Swimming.
Swimming is another popular recreational activity throughout the SR-HC TMDL reach. Swimming activities are usually linked with other recreational use activities such as boating, camping or hiking; and as such, have increased with the increase in recreational use observed following completion of the Hells Canyon Complex reservoir system. Most swimming use occurs during the summer and fall months. Because of its close correlation with other recreational activities, swimming use is also affected by the water quality of the SR-HC TMDL reach, and by flood control and storage operation of the reservoir system.

Camping.
Camping use varies by reservoir and river reach. Many campers choose their destination based on proximity to other recreation activities, particularly boating and fishing. The reservoirs and rivers in the SR-HC system are important destination recreation sites for overnight visitors who travel to the sites to camp and participate in a variety of water-related activities (USBR, 1998). There are a number of camp sites available along the mainstem Snake River, ranging from well-groomed camp grounds equipped with modern facilities maintained by Idaho Power Company (IPCo) along the reservoirs to primitive camp sites used by white water boaters below the Hells Canyon Dam.

2.1.2.2 History and Economics

The economies within the SR-HC TMDL reach are strongly dependent on the Snake River in several ways. Water is a scarce commodity in the area and helps to fuel local business and industry through agriculture, recreation and hydropower generation. The economy of the Snake River Basin is fueled in large part by agriculture. Together with food processing, agriculture represents 23 percent of Idaho's Gross State Product (IDC, 1999). Agriculture in the Snake

River Basin is heavily dependent on irrigation. Sources of irrigation water include surface water diverted from the Snake River and inflowing tributaries, and ground-water pumping. Agricultural water use is seasonal, correlating strongly with the summer growing season reflecting local temperature and precipitation variations. While still providing the primary economy of the basin, agriculture is slowly being replaced by urban/suburban encroachment and industrial land uses.

In the early 1900's, over 90 percent of Idaho's population was rural, by the 1950's rural population dropped to about 50 percent of the total, in 1998 this figure had dropped to 36 percent. Over the last 10 years the number of farms and farm acres have decreased in the State of Idaho, down by nearly 20 percent between 1969 and 1997. The number of individuals listing their primary occupation as farmer on the 1997 Census of Agriculture decreased by 17.2 percent between 1987 and 1997 (IDC, 1999) alone. As the local population increases, recreational usage of the SR-HC system has also increased. Recreation now represents a significant contribution to the economy in populated areas of southwestern Idaho and the Hells Canyon National Recreation Area (NRA), while in some rural counties recreation-induced costs actually represent a drain on the local economies. Most recreational use within the watershed occurs during the summer season, but some level of recreational use occurs year round. Most recreational use in the SR-HC TMDL reach is dependent on water quality (swimming, boating, whitewater recreation) and aquatic habitat (fishing).

In addition to the increased use of surface water for recreation purposes, the growing population in the region has also resulted in increased electrical power demand. While hydropower plants are expensive to construct, they can represent a more environmentally friendly and relatively economical alternative to more expensive mechanisms of power production such as coal-fired facilities. However, there is recent evidence and analysis to show that the environmental, social, and cultural costs of large hydropower systems may be much higher than for other types of power generation (World Commission on Dams, 2000). One of the externalized costs associated with the Hells Canyon Complex is that in order to operate effectively, there must be a manipulation of naturally occurring flows. This manipulation can present challenges to water quality and aquatic habitat, e.g. the migration of anadromous fish species. With the West Coast currently experiencing substantial power shortages, operation of hydroelectric facilities is viewed by many as equally important to the local economy as agriculture or recreational water uses.

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